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ABSTRACT

Hypermedia computing now makes it possible to integrate media into interactive programs with the potential to expand the use of visualization in science, art, and other professional disciplines. After an overview of some visualization issues in hypermedia, a research project called "HyperGlyphs" at Rensselaer Polytechnic Institute in Troy (New York) is described. HyperGlyphs use art professionals and computer scientists to develop guidelines for designing hypermedia interfaces to facilitate navigation and information retrieval. The research design uses three essential criteria: an abstract art database, an interdisciplinary team of art professionals and computer scientists, and a methodology of iterative design. Development has involved the following steps: (1) defining the semantic structure of the program; (2) using graphics and language to visualize the program structure; and (3) designing a navigation function to visualize the user's path through the database. The interaction of the diverse perspectives of those working on the project has enriched it in many ways. This interaction will lead to the development of multidimensional communication modes that integrate audio-visual stimuli and cognitive information structures into an expansive view of reality. (Contains 10 references.) (SLD)

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The Art and Science of Hypermedia

by
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Throughout history, scientists and artists have used visual imagery to further their understanding of the world around them. In the twentieth century, advances in electronic technology, in particular computer graphics, have culminated in a new emphasis on the role of perception and visualization in art and science. Artists are using computer graphics and video to establish new forms of creative expression that challenge the limits of traditional media. Scientists, in turn, have access to high-speed computers that can turn their mathematical data into three-dimensional, animated graphics.

Until recently, the principle tools for electronic imaging in science and art were three-dimensional modeling, computer animation, and motion video. However, hypermedia computing now makes it possible to integrate these media, as well as text and audio recordings, into interactive programs that have the potential to expand the use of visualization in science, art, and other professional disciplines. Hypermedia is a powerful tool for restructuring conceptual relationships. Hypermedia programs allow users to randomly access information which makes it easier to create associations and synthesize ideas. In addition, multimedia databases provide

a wide range of interpretive elements that enable users to evaluate information from different perspectives.

However, in order to tap the true potential of this medium as a visualization tool, users need interfaces that allow them to easily navigate through the database and retrieve information. This paper begins with a brief overview of some of the visualization issues in hypermedia interface design and describes a project called **HyperGlyphs**, a research project that is using a team of art professionals and computer scientists to develop guidelines for designing hypermedia interfaces. This paper highlights the results of this research and shows how the unique perspectives of artists and computer scientists have contributed to the successful resolution of conceptual and technical problems in hypermedia interface design.

Visualization in Hypermedia Interfaces

In order to use hypermedia to define new perspectives and conceptual relationships, the user must be able to easily access and organize information that is available in a large, multimedia

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database. In hardcopy media, there are temporal and spatial references for the user that indicate the structure and location of information. For example, by looking at the physical size of a book and by quickly flipping through the pages, a reader can see how much information is available and how that information is organized. However, with interactive computer programs, information appears and disappears on the screen as new visual data is displayed, leaving the user with few orientation references for accessing and retrieving data. As a result, users tend to become lost and disoriented as they navigate through a hypermedia database.

At Rensselaer Polytechnic Institute, a group of artists, art librarians, curators, and art historians are working with a team of computer scientists to resolve these problems in a research project called **HyperGlyphs**. The project is using a hypermedia program on contemporary art to develop guidelines for designing user interfaces that facilitate navigation and information retrieval. The research design of the HyperGlyphs project uses three essential criteria to achieve these objectives: an abstract art database, an interdisciplinary team of art professionals and computer scientists, and a methodology of iterative design.

The art database consists of images of abstract, contemporary art and conceptual writings about the art. Working with this type of symbolic information enables us to focus on the underlying visual and cognitive relationships between images and words without being distracted by representative and stylistic variables. This approach also makes it easier to identify new levels of interaction between language and design

that can be used to visualize the information hierarchies in the user interface.

The research team consists of a group of art professionals and computer scientists. The art professionals comprise a focus group which plays an important role in the project because these professionals understand the power of visual perception and design in the communication process. In particular, they are sensitive to the interrelationships between words and images and can quickly identify the types of spatiotemporal cues that are needed for orientation and information retrieval.

Throughout the research, the HyperGlyphs project is using a process of iterative design to evaluate and modify the structure of the program and the interface screens. We began by interviewing the focus group to define the user's tasks and the objectives of the program. The program structure and the interface screens were designed and modified on paper before any code was written. Over 60 hours of interviews resulted in more than 300 iterations of screen designs. By developing preliminary designs on paper, we were able to evaluate issues of perception and cognition in hypermedia interfaces without being distracted by the technical problems that arise during software development.

When the focus group study was completed, we began developing a prototype program to implement the ideas that we had developed on paper. The process of iterative design continued as the computer scientists and the art professionals worked together to improve the conceptual and visual design of the program. The roles that both groups

played in this process will be discussed in more detail later.

Designing Hypermedia Interfaces

In the HyperGlyphs project, the development of the user interface involved three major steps: (1) defining the semantic structure of the program; (2) using graphics and language to visualize that structure; and (3) designing a navigation function to visualize the user's path through the database.

Defining the Semantic Structure of the Program

In order to reduce confusion and enhance the creative output of the user, a hypermedia program must have a well-defined, semantic structure that is based on a conceptual model of the user's tasks. Research has shown that if users understand the structure of a document, they can use the program to their maximum advantage (Wright, 1991). It is important that the user interface establish a clearly articulated parallel between the user's tasks and the program design. The following steps can be used to accomplish this objective:

- Define the user's tasks;
- Map the tasks to specific program functions;
- Organize the database into a relational model;
- Identify the correlations between browsing and searching.

Define the user's tasks. The first step in defining the semantic structure of a hypermedia program is to analyze the

objectives of the end user. As previously mentioned, we conducted over 60 hours of interviews with the focus group to determine the user's tasks and the objectives of the program. In addition to identifying conventional methods of organizing information, the focus group tried to specify new methods of accessing and structuring information that would only be feasible with an electronic database.

Map the tasks to specific program functions. The focus group carefully outlined the steps that were needed to accomplish each task and then mapped those steps to specific program functions. Cognitive walkthroughs (Lewis, Polson, Wharton, and Rieman, 1990) helped the group define the syntax of each function and in turn, visualize the human-computer interaction in the program. The research team and the focus group developed paper designs of the interface screens and continually evaluated and modified the user interface to clarify the conceptual model. Studies have shown that accurate cognitive maps are a requirement for successful navigation in hypermedia databases (Simpson and McKnight, 1990).

Organize the database into a relational model. A large database must be organized into chunks of information with labels that serve as orientation flags for the user (Wright, 1991). This step is accomplished by identifying the cognitive relationships between individual tasks and organizing the information in the database into small, task-oriented groups that support the user's objectives. This relational model creates a semantic structure that improves the effectiveness and efficiency of user navigation in a large

database (Hara, Keller, and Wiederhold, 1991).

The conceptual breakdown of a multimedia database must be tailored to the needs of each application and target audience. In the HyperGlyphs project, the focus-group study indicated that a "narrow but deep" program structure was best for the end user. In this type of structure, the top level of the information hierarchy is restricted to a few groups but within each group, there are numerous links to information in the database. For example, in the HyperGlyphs program, there are only four categories in the top level of the program: Artwork, Exhibits, Bibliography, and Biography. Within each of these categories, the database is broken down into smaller groups of information which are defined by specific program functions.

Identify the correlations between browsing and searching. In hypermedia programs users must be able to browse and search for information as well as backtrack to retrieve information. It is difficult to specify the semantic structure of program functions that allow the user to accomplish these tasks because it is not always possible to delineate the conceptual boundaries between "browsing" and "searching."

For the user who needs to access specific information, it is easy to design a keyword search that allows the user to query specific information. Most users, however, tend to migrate back and forth between different levels of browsing and searching. Typically, users begin by casually browsing through a database. As they browse, they may become interested in a specific topic and decide to search for more detailed information. Although

browsing inherently demands a flexible route into the database, the structure of the database itself must be clearly defined and labeled so that users can quickly search for specific information as needed.

The HyperGlyphs project addresses this problem with a *sort* function that allows the user to organize the information in the database according to a number of predefined categories such as year, author or artist, publication, and exhibits. This function provides the user with adequate flexibility for browsing through information, while at the same time, providing labels that enable the user to backtrack and locate specific data (see Figure 1). Researchers have pointed out that users are less likely to feel disoriented or lost when there is a predefined path that narrows their options for navigation (Zellweger, 1989).

Visualizing the Program Structure

Graphics as well as language are critical elements in visualizing the semantic structure of the program and the syntax of the program functions. Visualization techniques will vary with different hypermedia programs depending on the application. Examples from the HyperGlyphs project can provide some general guidelines for using color and layout, menus, and language to establish navigational cues for the user.

Color and layout. In the HyperGlyphs program, four icons represent the top-level divisions of the database (Artwork, Exhibits, Bibliography, and Biography). There are two versions of each icon: a colored version and a gray version. When an icon is selected, it is highlighted in color to serve as an orientation reference while the

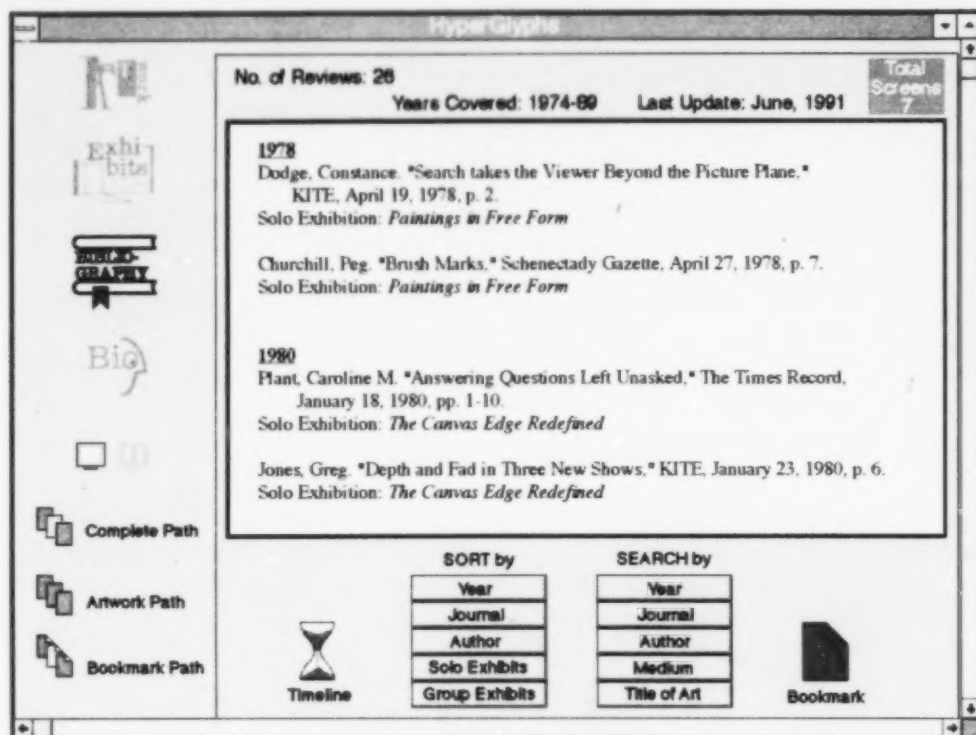


Figure 1. A *sort* function allows users to sort all the information in the database according to predefined categories. This function enables users to browse or locate specific data. Another function that performs keyword searches is also available for highly structured queries.

other icons remain gray. Each icon is characterized by a unique color which is repeated in a slightly lighter value in other graphics that appear on the screens within each of the main categories (e.g., the timeline and bookmark icons). This color coding provides the user with a visual outline of the program structure.

The layout of information on the screens also plays an important role in the visualization of the program structure and the syntax of the program functions. The four main icons are arranged in a vertical list to reflect the top-down hierarchy of the program structure. The buttons for

the *sort* and *search* functions are also arranged vertically to underscore the hierarchical structure of the program and to emphasize the parallel syntax of the two functions.

Menus. The HyperGlyphs program uses permanent menus that are visible at all times (as opposed to pull-down or pop-up menus) to identify the user's location in the database and to remind the user how to access information. This design reduces the cognitive overhead for the user because once information is located, it is not necessary to remember all the steps that

were required to get to that section of the database. Research has shown that repetition is an important navigational aid in speech-controlled hypermedia programs (Barry, 1991). However, the use of repetition as a navigational aid should not be restricted to audio programs. By keeping menu options visible at all times in a hypermedia program, repetition can also be used to facilitate navigation and information retrieval in audio-visual interfaces by simplifying the perceptual complexity of the multimedia stimuli.

Language. In the HyperGlyphs project, language is also an important design element in the visualization of the database structure and the syntax of the program functions. For example, in the user interface there are textual lists of options for database sorts and keyword searches (see Figure 1). These categories define the organizational structure of the database and provide labels for navigation and information retrieval. Language is also used to define the syntax of functions and direct the input of the user. For example, the phrase "Search by..." is located at the top of the list of options for the keyword searches. The focus group evaluated the phrases "Search by..." and "Search for..." as possible headers for the list. "Search by..." was selected because the phrase tends to limit the user's input to a specific list of requests while "Search for..." implies that the user is free to search for a much wider range of information--a process that can lead to confusion and disorientation in the program.

In the design of human-computer interfaces, there has been considerable support for the use of "natural language" in interactive computer programs because

natural dialog is an inherent part of social interaction and because it can be incorporated into a wide variety of media and forms of communication (Waterworth and Chignell, 1989). In the HyperGlyphs project, language is an important visualization tool that improves navigation by clarifying the interpretation of the program's structure and interactive functions.

Designing a Navigation Function

Hypermedia programs should provide a method of visualizing the user's path through the database. Research has shown that hypermedia navigation is improved if the user can see a list of all the information that has been accessed (Simpson, 1989). Many hypermedia programs have implemented navigation functions that track the user's path and attempt to accomplish several, if not all, of the following objectives:

- Allow the user to backtrack and retrieve information;
- Locate the user's position in the database;
- Identify what information has been accessed and what additional information is available;
- Show the hierarchical and associative links in the database.

These multipurpose navigation functions often use tree-structure diagrams to visualize the hierarchical and associative links in the database and the user's position in the database structure (a "You are here" approach). However, a navigation function that attempts to show too many relationships contributes to the confusion of navigating through a

hypermedia database. The objectives of a navigation function should be clearly defined and limited to a single goal. For example, if the purpose of the navigation function is to allow the user to backtrack and retrieve all the information that the user has previously accessed, the path does not have to show all the remaining, unaccessed information in the database. Program functions that provide overviews of the database or functions that allow the user to sort or search for information can provide that type of feedback.

The HyperGlyphs project limits the objectives of the navigation function to backtracking and information retrieval. The focus group evaluated several

methods of visualizing the path, such as overlapping windows and small icons of the screens, but rejected those approaches because they were technically and perceptually unfeasible for the visualization of long navigation paths. The final solution was a textual list of references to the information that the user has accessed (see Figure 2). This linear, sequential representation of the user's path through the database accurately represents the temporal characteristics of the user's interaction with the program. Although hypermedia programs support non-linear, random access to information, the *sequence* of user actions is really a linear, one-directional event that occurs over time.

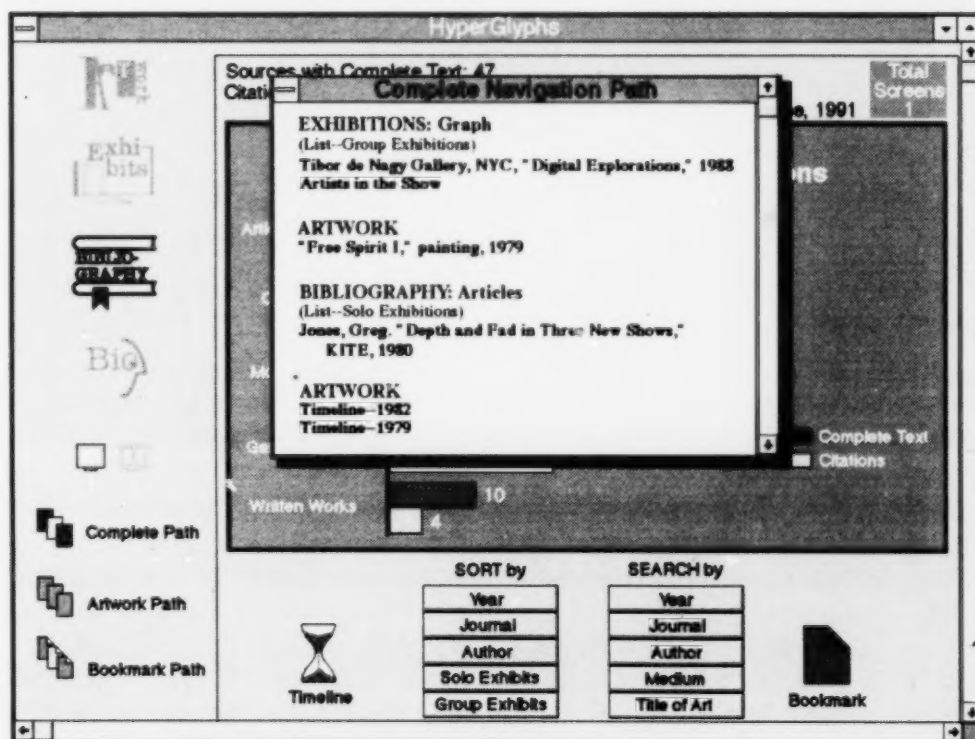


Figure 2. The navigation function tracks the user's path and uses typographical cues to designate the different screens of information that the user has accessed. The user can return to a screen by selecting an item from the list.

Formatting this list for readability and comprehension posed several problems. Indenting the references under their respective categorical headings created a conceptual hierarchy that did not necessarily reflect the user's associations between the ideas. The current format in the program uses left-justified text with variations in typography to differentiate the steps in the path (see Figure 2). These visual cues allow the user to easily locate individual entries without defining conceptual hierarchies. Future versions of this navigation path will use color and icons to enhance the textual list.

The Interaction of Art and Science

Hypermedia interfaces must visualize the semantic structure of the program, the organization of the database, and the syntax of the program functions. The interface design must clearly articulate a conceptual model of the user's tasks and objectives.

In the HyperGlyphs project, the art professionals and computer scientists contributed distinctly different perspectives to the research. Computer scientists, for example, are trained to focus on the product of the programming design not the process itself (Linn and Clancy, 1992). As a result, our programmers were quick to propose existing software conventions for solutions to problems, instead of letting the problem-solving process itself define solutions that were tailored to the objectives of the application. The computer scientists also focused on the syntax of the programming language and often used the interface design to visualize

the syntax of the underlying software rather than the user's tasks.

The art professionals, on the other hand, were able to define the user's tasks and visualize the procedures that were required to accomplish those tasks. They were able to define the semantic structure of the program and the syntax of the program functions by analyzing the steps that were needed to accomplish each task, and they were able to identify parallel relationships between tasks and procedures. They did not enter the project with any preconceived ideas about the way the program should be designed. Instead, they let the *process* of defining the program structure dictate the conceptual and visual design of the interface.

The interaction of these diverse perspectives enhanced the project in many ways. By working with designers who could visualize the semantic relationships in the program, the computer scientists gained new insights into ways to access data and structure links in the database. In turn, by subjecting all the conceptual proposals of the focus group to the logical scrutiny of the computer scientists, it was possible to uncover some of the subtle ambiguities in verbal and visual communication that can create confusion in hypermedia navigation. For example, the focus group recommended the implementation of a function that would allow the user to move back and forth between screens of information by using buttons labeled "Previous Step" and "Return." However, when the programmers tried to develop an algorithm for this function, they identified conceptual problems with this approach because neither term specified exactly

how far the user would move. The term "Previous Step" could mean one step back, several steps back, or all the way back to the beginning. Similarly, "Return" does not specify how many steps the user will move nor does it indicate direction (forward or backward). A logical analysis of the algorithm for the function revealed conceptual ambiguities that the cognitive walkthroughs in the focus-group study had not identified.

Conclusion

Although scientists and artists analyze problems from diverse perspectives, both groups share a mutual need to use visualization to define and clarify relationships. Martin Kemp points out that visual imagery has created an historical affinity between the sciences and the visual arts because through vision, scientists and artists can study nature and understand the rules that define the underlying structure of the real, physical world (Kemp, 1990).

However, in the HyperGlyphs project, this intellectual affinity involved more than the use of visual perception to understand the physical environment. The communication objectives of this project required the use of visualization techniques to articulate task-oriented procedures. As a result, the perspectives of scientists and artists were linked by the mutual need to identify the underlying, logical structure of the visualization process itself. At all stages of the research, the computer scientists, artists, art librarians, curators, and art historians used varying degrees of logic to transform complex observations into visual statements that defined a set of procedures. The art professionals used

the logic and resolution defined by the Gestalt laws of perception and the semiotics of design, while the computer scientists used the analytical perspectives that are rooted in the scientific logic of discrete mathematics. Both groups had to define a logical structure that could translate the abstract process of perception into concrete functions that would enable the user to accomplish a set of tasks.

This emphasis on the use of electronic imaging to visualize abstract, interactive processes can be seen in many areas of scientific research and in many forms of contemporary art. This mutual need to visualize the underlying structure of perception and cognition is breaking down the conceptual barriers between science and art and creating a dynamic dialog between professionals in both fields. This interaction will lead to the development of multidimensional communication models that integrate audio-visual stimuli and cognitive, information structures into an expansive view of reality. In the area of user interface design, these communication structures will lead to "transparent" interfaces that make it easier for users to organize information and visualize new relationships.

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